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Bioenergetic analysis of female volleyball

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BIOENERGETIC ANALYSIS OF FEMALE VOLLEYBALL

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Volleyball is a demanding sport typified by repeated high intensity bouts of activity consisting of jumping, spiking, diving, and running. Practice sessions for collegiate level play generally last from two to three hours. The total energy requirement for extended practice sessions has not been directly measured and compared to dietary intake to assess whether collegiate athletes' energy intake meets the energy demand of the sport. The purpose of this study was to establish the energy balance of female collegiate volleyball athletes during typical team training days. A bioenergetic analysis was conducted by directly measuring oxygen consumption (VO_2) during actual training sessions, analyzing detailed records of the energy cost of all other activities throughout training days, and comparing the total kcal cost of activity to the dietary intake of athletes.

Twelve female collegiate volleyball athletes (20.5 ± 1.2 years of age) were asked to wear a portable metabolic measurement device for approximately 45 min during their regularly scheduled team practice sessions under the direct supervision of team coaches;

data from one athlete was excluded due to illness on data collection days. Athletes kept detailed records of all physical activity and dietary intake for three 24 hour periods on three regular team training days.

The mean VO_2 during on-court data collection was 25.03 ± 3.12 ml/kg/min during approximately 47.1 ± 3.7 min of volleyball play. The mean energy cost during on-court data collection was 419 ± 85 kcal. Analysis of activity records of the three 24 hour periods on team training days revealed a mean daily energy cost of 3630 ± 442 kcal. The mean daily kcal intake from dietary records was 1861 ± 516 kcal. There was a significant difference ($p = 0.001$) between the energy expenditure (EE) and the energy intake (EI) revealing a negative 1769 ± 507 kcal balance which represented a 48.7% negative energy balance. In conclusion, this study revealed greater EE on training days compared to EI and pointed to a need for further research to investigate nutritional supplementation and/or education to help athletes attain an optimal energy balance essential for health, training, and performance.

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Chapter 1. Introduction

Volleyball is a popular sport characterized by skilled high-intensity bouts of activity including jumping, spiking, blocking, diving, and running. Games typically consist of 50 rallies lasting 10 seconds or less followed by 12 to 14 seconds of rest (Black, 1995). During competition play, a five game match can last about two hours, and during tournament play as many as three matches might be played in one day. This could add up to over six hours of playing time in one day. Practice time for collegiate volleyball teams during the preseason may consist of two sessions of two hours each per day. The energy requirements for this kind of repeated high intensity physical activity is likely to be considerable, but as yet has not been directly assessed.

Energy supply and demand are key components to athletic performance. Without adequate supplies of stored or immediately available energy, athletes will not be able to perform to their full potential. This is one reason that sports nutrition has become an ever increasing topic of importance among athletes and coaches who wish to optimize performance during practice and competition. The full potential of an athlete will go unrealized despite the best coaching and training efforts if the athlete is energy depleted or dehydrated before or during an important event (Clark, 1999). Nutrition becomes particularly important in athletes who may have poor body image and undue fear of gaining weight. Behavioral, psychological, and physical characteristics of female athletes with sub-clinical eating disorders have been described by Beals and Manore (2000) as including those who severely restrict food intake and try multiple ways to lose weight despite being at normal or within 5% below normal weight. Gutgesell, Moreau, and

Thompson (2003) studied the occurrence of eating disorders from two Division I National Collegiate Athletic Association (NCAA) universities and found that 18% of 149 female varsity athletes and 26% of 209 female controls had past or current eating disorders. Restriction of caloric intake can leave athletes without enough energy and nutrients to support their needs for training, competition, and recovery. Considering that the carbohydrate (CHO) requirement for athletes is estimated at 6 to 10 g/kg of body weight per day, it may be hard to consume that amount of CHO on a calorie restricted diet (Ray & Fowler, 2004).

Competition and high levels of training, typical of collegiate athletes, can have additional detrimental effects on the health of athletes. Pipe (2001) summarized recent research concerning the effects on the immune system following exercise. He reported that after prolonged and/or intense exertion there appears to be a reduced amount of natural killer cell activity which can lead to a suppressed immune response leaving an athlete more susceptible to infection. He further stated that these changes may be magnified by an overtrained status, lack of proper sleep, mental stress, weight loss, and malnutrition. The added stresses from training put an increased importance on adequate nutrition. Sufficient stored glycogen and fats are needed for energy, and essential fats and micronutrients are needed for the immune system and antioxidant protection (Venkatraman & Pendergast, 2002). Undernourished athletes will have a difficult time meeting these nutrient needs, and this may well lead to illness, lack of energy, and poor performance.

The energy requirements of each athlete are dependent on several factors: basal metabolic rate, thermic effect of food, thermic effect of activity, and growth (Burke, 2001). Many research groups have attempted to assess the energy expenditure of athletic endeavors using various indirect measures. Kimber, Ross, Mason, and Speedy (2002) estimated energy balance in 10 male and 8 female triathletes participating in a triathlon event of running, cycling, and swimming. They calculated the total energy expenditure (EE) by regressing heart rate (HR) to oxygen consumption (VO_2) from HR data obtained from the athletes during maximal treadmill running and cycle ergometry tests in the laboratory. Oxygen consumption for the swim portion was estimated from a regression formula developed using speed and body weight. Results of total EE were compared with energy intake (EI) from dietary recall of food and fluid intake. They found a large negative energy balance for these athletes with the EE (male, 10,036 ± 931 and female, 8570 ± 1014 kcal) significantly greater than the EI (male, 3940 ± 868 and female, 3115 ± 914 kcal, $p < .001$). Trappe, Gastaldelli, Jozsi, Troup, and Wolfe (1997) estimated EE of five female swimmers during high volume training days by using a doubly labeled water method. They found a 43 ± 2% negative energy balance for the five day training period which consisted of 5 – 6 hours of swimming per day. Similar results were found by Edwards, Lindeman, Mikesky, and Stager (1993) in a study of the energy balance of female endurance runners with the use of a doubly labeled water technique and a food survey. They found a 32% negative energy balance with the runners expending more energy than they reported taking in. The investigators of these three studies were in agreement that some underreporting of food intake was very probable with these athletes because there was no significant weight loss; the study period may not have been long enough for weight loss to be measurable.

Volleyball studies have reported many different physical characteristics of volleyball play but few were found that attempted to measure EE during actual play. Laconi, Melis, Crisafulli, Sollai, Lai, and Concu (1998) conducted a biomechanical study of the mechanical work efficiency of 10 volleyball players which included measures of VO_2 with the use of a telemetry device worn by the athletes. Results showed that during 15 min of volleyball play the athletes' average VO_2 for attacking was 23.1 ± 3.3 ml/kg/min with an associated energy cost of 0.12 ± 0.02 kcal/kg/min, and for defending the VO_2 was 18.9 ± 2.7 ml/kg/min with an associated energy cost of 0.09 ± 0.01 kcal/kg/min. Künstlinger, Ludwig, and Stegemann (1987) studied the metabolic changes in hormones (cortisol and aldosterone), urinary and serum concentrations of electrolytes (Na^+, K^+, Mg^{2+}, and Ca^{2+}) and lactate, glucose, and free fatty acids during volleyball play. They concluded that due to the low concentration of lactate and the relatively short exertion periods (9 s), energy during volleyball play was mainly supplied by the breakdown of creatine phosphate and that aerobic pathways restored energy supplies during the rest periods. A study by Bonetti, Catapan, Novarini, Pascale, Zeppilli, and Zuliani (1988) measured changes in lipid metabolism during volleyball play and found that HDL cholesterol and triglycerides showed significant increases following a match, but total cholesterol and apoprotein B had no significant changes. None of these studies measured EE for the duration of the observed playing time or estimated the energy necessary for typical games or team practice times.

Information about the EE of typical volleyball training sessions or the activities included during competition game days has not been found in current literature. Knowledge of EE could be valuable information for athletes and coaches to help ensure that adequate energy intake in the form of food or supplements are part of the preparation of the athlete. Therefore, the purpose of this study was to examine the bioenergetics of female collegiate volleyball players during an actual practice session in order to determine the total kilocalories (kcal) used. EE was assessed with the aid of a portable metabolic unit to collect and analyze expired air. The measured kcal value was then added to the estimated kcal used for other activities throughout that day to derive the total kcal expenditure for the day. A dietary diary was used to determine the kcal consumed on training days and this value was used to determine the energy balance.

Chapter 2. Problem

Purpose

The purpose of this study was to examine the bioenergetics of female collegiate volleyball players and to establish the energy balance of training days. Kilocalories (kcal) expended during actual volleyball play in a practice session was assessed with the aid of a portable metabolic unit. This directly measured EE was added to the estimated kcal expended in other activities throughout that day to derive the total EE for the day. A three day dietary diary was used to determine the mean kcal consumed on typical training days. The difference between the daily kcal intake and the daily kcal expended was used to determine the energy balance.

Hypothesis

There will be a significant negative energy balance during training for female volleyball players. The volleyball athletes will expend significantly more calories than they consume on typical days of team practice sessions.

Delimitations

Twelve female collegiate volleyball players from the University of Nebraska at Omaha's NCAA Division II team participated in regularly scheduled team practice sessions for approximately 45 min while wearing a portable metabolic measurement device. The practice sessions included team warm-up, team drills of six-on-six volleyball play action, and drills for specific team positions. The practice sessions were performed during the team's off-season training period in the UNO Sapp Field House and under direct supervision of the team coaches. A portable metabolic device was fitted on the subject to measure the VO_2 and analyze the expired air during training. This data was used to estimate total EE during the practice session. Within two weeks prior to field data collection, the athletes received detailed instructions on how to complete a dietary diary and a physical activity inventory that were maintained for three regular training days. Information from the diaries along with the measured EE during the volleyball practice session was used to determine EE and EI. Energy balance for the day was calculated by the difference between EI and EE. Preliminary tests were performed on a separate day before on-court data collection to determine descriptive characteristics for height, body weight, and percent body fat. Following these descriptive measurements, subjects performed a 5 to 10 min exercise test consisting of running, jumping, and hitting the volleyball while wearing the portable metabolic unit to familiarize them with wearing the device during activity.

Limitations

One limitation for this study was the restriction of some movements of the athlete while wearing the portable metabolic unit (VO2000). Typical action in volleyball includes diving for the ball and rolling on the floor as a recovery movement. These movements could not be performed for safety of the athlete and protection of the equipment. Also, the athlete may have felt restrained because of the face mask and harness of the VO2000. It is also possible that play action of other teammates may have been altered to some degree because of their concern for the athlete wearing the VO2000.

Another limitation was the accuracy of the self reported daily food diary used to estimate EI. Underreporting of food intake either because of failure to report or undereating during the recording period have been cited as a problem in studies of comparisons of EI and EE (Burke, 2001). A similar limitation existed for the self reported daily activity log used to estimate EE of daily activities other than volleyball because of possible overestimation or underestimation of time spent in activity (Ainslie, Reilly, & Westerterp, 2003). An additional associated limitation was the assumption of a resting metabolic rate of 3.5 ml/kg/min for all subjects which was then used in the estimation of EE of activities other than volleyball from the energy cost of physical activities listed in the Compendium of Physical Activities (Ainsworth, 2002).

Definition of Terms

Bioenergetics: The biology of energy transformations and energy exchanges within and between living things and their environment. (Merriam-Webster Dictionary, 2003).

Energy balance: A state when energy intake equals energy expenditure over a specified period of time (Position of the American Dietetic Association, 2000).

Energy expenditure (EE): The sum of kcal used for resting metabolism, the thermic effect of food, all voluntary physical activity, and growth during a specified period of time (Burke, 2001).

Energy intake (EI): The sum of kcal consumed in the form of food, fluids, and dietary supplement products over a given time period.

Oxygen consumption (VO_2): The rate at which oxygen is used by the body (Biology-Online Dictionary, 2006). The unit of measurement for this study was ml/kg/min.

Significance of Study

Nutrition is a key factor for the optimal performance of athletes during training sessions and competitions as well as for recovery and maintenance of health. Many studies have attempted to measure the energy balance of athletes and have concluded that a significant negative balance existed for the subjects whom they studied (Kimber et al., 2002; Trappe et al., 1997; Hassapidou & Manstrantoni, 2001; Edwards et al., 1993). In order to make nutritional recommendations, an accurate estimation of EE is needed. The purpose of this study was to measure the EE of female volleyball players during actual practice sessions through indirect calorimetry and to add that value to the EE of all other activities to arrive at an estimation of total EE for a typical practice day for collegiate volleyball athletes. A comparison of the EE to the EI derived from dietary diaries was used to estimate the energy balance. Information of the actual EE of volleyball practice sessions and energy balance for a typical training day will add to the present knowledge of the bioenergetics of volleyball and may be useful for nutritional recommendations for athletes who want to optimize their performance.

Chapter 3. Review of Literature

Introduction

The review of literature is divided into three sections. The first section is the Nutritional Status and Practices of Athletes which includes studies of competitive athletes from different sports assessed for their current nutritional status and practices during competition. Next is a section addressing studies that have researched the Energy Intake and Expenditure of Specific Sports. The final section contains a review of studies regarding the Characteristics of Volleyball Players and includes reports of the physiological changes that occur during volleyball action. A summary will conclude the review.

Nutritional Status and Practices of Athletes

Nutritional status is a concern of many coaches and athletes for reasons of health and performance. Energy supply and demand during practice and competition are directly related to the overall nutritional status of athletes. Heffner, Ogles, Gold, Marsden, and Johnson (2003) stated that coaches have a major role in the physical and psychological health of their athletes. They conducted a study by surveying coaches of female college athletes to determine the coaches' knowledge of nutrition and their attitudes toward the monitoring or managing of athlete eating and weight. Six hundred coaches for gymnastics, swimming, basketball, softball, track, and volleyball from NCAA and National Association of Intercollegiate Athletics (NAIA) colleges and universities were randomly chosen and sent detailed questionnaires dealing in six subject matters: demographic information, coaching behaviors, availability of prevention/intervention services for athletes, awareness of general nutritional health issues, eating and weight-related problems with athletes, and attitudes toward eating and weight in the sport. They received 303 responses (51% response rate). Of the 303 coaches, only 33% had formal training in diet or nutrition; however, 44% of the coaches indicated that they had their athletes weighed, 44% had athletes' body fat composition assessed, 30% had recommended that athletes try to lose weight either by restricting food intake or by extra practices or workouts, and 28% had monitored eating patterns. These results led Heffner et al. to conclude that a large proportion of coaches had demonstrated unhealthy attitudes or behaviors associated with athletes' eating and weight. They further recommended that coaches be informed of the potential risks connected with attempting to monitor or manage athlete eating and weight because of its possible connection with the development of eating disorders. Additionally, Heffner at al. suggested that coaches should refer athletes with unhealthy weight or eating problems to those with more training and to those who were not pressured to produce elite athletes such as dietitians, athletic trainers, or physicians.

An assessment of the dietary intakes and behaviors of 345 NCAA Division I athletes (165 female, 180 male) from 13 varsity sports was conducted by Hinton, Sanford, Davidson, Yakushko, and Beck (2004) with the use of a food frequency questionnaire, the Youth Assessment Questionnaire, which had been reported to be reproducible and valid for people 9 to 18 years old. The athletes also voluntarily completed a questionnaire for eating disorder diagnosis. Analysis was based on the joint position stand of the American Dietetic Association, Dietitians of Canada, and the

American College of Sports Medicine on nutrition and athletic performance (2000) general recommendations that daily CHO intake for athletes is 6 to 10 grams per kilogram of body weight and daily protein need is 1.2 to 1.7 grams per kilogram of body weight. Hinton et al. found that the mean kcal intake for females was below but near the recommended level for adult women who participate in light-to-moderate activity (2141 vs. 2200 kcal/day, $p < 0.01$), but the males were about 400 kcal below recommendations for young adult men (2447 vs. 2900 kcal/ day, $p < 0.01$). Results from the eating disorder questionnaire showed that 62% of the female athletes wanted to lose at least five pounds compared to 23% of male athletes, and athletes who wanted to lose weight were more likely to have reported that they restricted their fat or CHO intake. Eighty-one percent of female athletes and 90% of male athletes fell below adequate CHO recommendations ($p < 0.01$), and 68% of females and 81% of males were not getting adequate daily protein ($p < 0.01$). Hinton et al. suggested that the wide-spread undereating could have detrimental effects on both the health and performance of these athletes. They strongly suggested an intervention of educating athletes about their nutritional needs for energy, CHO, and protein during the early part of their training season. They acknowledged the limitations of survey instruments for analysis of energy and nutrient intake: underreporting, ability of subjects to recall foods and serving sizes, and subject compliance. Hinton et al. recommended improving the quality of dietary assessment by a comparison of written diet records to EE determined by the doubly labeled water technique.

Nutritional supplement use, the sources of nutritional information, and the reasons for using supplements were the topics of a study by Froiland, Koszewski, Hingst, and Kopecky (2004) who surveyed 115 male and 88 female college varsity athletes. Athletes were from a NCAA Division I university and represented 12 female and 9 male varsity sports. Froiland et al. reported that 89% of the college athletes had or were currently using supplements, and the reasons they used them were for strength and power, for health, and for supplementation of inadequate diets. Female athletes were found to take supplements significantly ($p < 0.05$) more for health reasons or because of inadequate diets than for any other reasons while males reported taking supplements significantly ($p < 0.05$) more for increasing strength/power and speed/agility than any other reasons. Surveyed athletes were allowed to select as many information sources as applied and reported to obtain their information about supplements from family members (32.4%), fellow athletes (31.9%), friends (28.5%), athletic trainers (30%), registered dietitians (28.5%), or coaches (28%). Froiland et al. recommended that registered dietitians, athletic trainers, and coaches be able to provide accurate and appropriate information about nutritional supplementation because of their close contact with athletes and their ability to detect possible eating disorders. This study pointed out the prevalence of supplement use, and the authors were in agreement with Heffner et al. (2003) about the importance of having nutritional training for the people who work closely with athletes. Other studies have gone beyond quantifying the use of supplements by taking a more comprehensive look at the total nutritional status of athletes who participate in long duration events.

The nutritional status of heptathletes was studied by Mullins, Houtkooper, Howell, Going, and Brown (2001) who were interested in assessing whether heptathletes were adequately nourished to meet the demands of their sport. They analyzed 19 female heptathletes (26 ± 3 years) for their overall nutritional status to compare it with the nutritional needs from the long hours of training and competition. All heptathletes were evaluated for height, weight, body composition (skinfold), iron level (blood analysis), dietary nutrient intakes (four-day diet record), and dietary practices (questionnaire about vitamin, mineral, protein, and other supplements). Results were compared with the National Health and Nutrition Examination Survey III (NHANES) for women 20 - 29 years old. The heptathletes' average for energy consumption was 2357 kcal/day (36 kcal/kg of body weight): protein = 16% of total calories, CHO = 57%, and fat = 27%. The average protein and CHO intakes were significantly higher ($p = .016$ and $p = .005$, respectively) than those of the NHANES III. However, Mullins et al. reported that the athletes' average CHO intake of 5.2 ± 2.2 g per kg of body weight was still below the recommended 6 - 10 g per kg of body weight for athletes who train vigorously. Despite the lower level of CHO intake, Mullins et al. concluded that overall the heptathletes were adequately nourished to support their training levels because they were obtaining greater than 67% (the level associated with the possibility of inadequate intake) of the Dietary Reference Intakes. Although this study assessed the nutritional intake of the athletes, it did not evaluate the average EE during practice to compare it for energy balance.

Energy Intake and Expenditure of Specific Sports

A method to examine nutritional status with bioenergetics in mind is to study EI and EE of athletes to determine if they reach an energy balance optimal for health and performance. One such study was that of Kimber, Ross, Mason, and Speedy (2002) who compared the EE of triathletes during competition with the EI during the same time period. They investigated ten male and eight female triathletes by starting with baseline measurements for body composition (skinfolds), weight, height, VO_2max on a treadmill test, and VO_2max on a cycle ergometer test. All the triathletes competed in the same Ironman Triathlon event (3.8 km swim, 180 km cycle, and 42.2 km run). During the event, food and fluids (Moro bars™, Power Bars™, bananas, oranges, chocolate chip cookies, water, Coca Cola™, and Powerade™ sports drink) were available at stations every 12 km on the cycle course and every 1.8 km on the running course. Triathletes were unrestricted for the amount of fluids and food they consumed, and records were kept of all EI during the event. The EE for the cycling and running portions of the triathlon was calculated using heart rate-VO_2 regression equations, and the EE of the swim portion was calculated with a multiple regression formula developed by Montpetit, Cazorla, and Lavoie (1988). The total EE during the triathlon was compared to the total EI during the event and results showed that total EE (male, 10,036 ± 931 and female, 8570 ± 1014 kcal) was significantly greater than total EI (male, 3940 ± 868 and female, 3115 ± 914 kcal, $p < .05$). The triathletes consumed a large quantity of calories during the Ironman event to support their EE, but they still had a large negative energy balance. There were two notable differences between male and female athletes. First, during the run portion of the race, the finishing time for males was inversely related to CHO intake ($r = -.75$, $p < .05$) but not for females. Kimber et al. suggested that the increased CHO intake may have been a helpful strategy for males. Second, there was a significant positive correlation between the total CHO ($r = .72$, $p < .05$) and cycle finishing time ($r = .77$, $p < .05$) for female athletes which suggested to them that something other than CHO intake was related to improved performance for females. One notable limiting factor here was the small sample size. Kimber et al. concluded that despite the negative energy balance for both males and females that the EI was adequate for all athletes to finish the Ironman before reaching exhaustion because athletes were able to derive about 59% of their energy from endogenous fuel stores. Interestingly, both Mullins et al. (2001) and Kimber et al. concluded that the athletes were adequately nourished to match their energy needs for training and competition; Mullins et al. by the comparison of dietary intakes to Dietary Reference Intakes and Kimber et al. by the observation that athletes were able to finish the triathlon before reaching exhaustion. Neither author speculated as to whether athletes might have performed better if EI had equaled EE. These studies also did not directly measure EE during the exercise period which may have affected their results when EE was compared to the actual EI.

Frentsos and Baer (1997) evaluated the effect of increasing the energy intake of triathletes during training and competition. Six elite triathletes (4 male, 2 female) were tested for body composition and completed a 7 day diet history of all food and fluids consumed. Average kcal, CHO, fat, and protein intake were calculated from the diet histories using the Nutritionist IV software and results were compared to the Diabetic

Food Exchange list for the actual number of servings of exchange groups consumed and the recommended number of servings needed for estimated energy and nutrient requirements of endurance athletes. Athletes were instructed to maintain current eating habits while they participated in a short course triathlon consisting of a 1.3 km swim, 40 km bicycling course, and 10 km run. Precompetition and during competition food and fluid intakes were recorded. Frentsos and Baer found that athletes were consuming too few kcal to meet their estimated EE (2,318 ± 150 kcal/day vs. 4,000 ± 250 kcal/day, $p < .05$). They stated that the triathletes' CHO intake was significantly below the recommended amount needed to support endurance athletes (4 ± 2 g/kg/day vs. 9 - 10 g/kg/day, $p < .05$), and athletes were not consuming the minimum daily servings recommended for milk and vegetables for a healthy diet: 2 - 4 servings of milk and 3 - 5 servings of vegetables. Following the trial triathlon, athletes were given counseling about their diet and how to modify current intake to meet recommended numbers of servings for specific food groups in order to meet their estimated energy and nutrient need. Subjects were also instructed to supplement pre and post training snacks with an additional 480 kcal containing 88 gm CHO: 8 oz Innergize (a liquid sport drink) and one Ultra Bar (40 gm). After four weeks of practicing the dietary recommendations, body compositions and a second 7 day diet record were obtained. The athletes then participated in an identical short triathlon. Results showed that following nutrition intervention, athletes consumed adequate kcal to support EE (3,992 ± 425 kcal/day), and there was a significant improvement in performance time of the triathlon (5 hr vs. 5 hr 25 min, $p < .05$). This study pointed to the importance of adequate kcal to support EE, and

Frentsos and Baer concluded that nutritional intervention was successful in increasing triathletes' daily EI to meet estimated EE and it did so without changes in body weight or body composition. Similar to the study of Kimber et al. (2002), this study had the limitation of a small sample size, and neither study measured EE during exercise with direct measurements of VO_2 to obtain actual EE. Kimber et al. estimated energy needs from heart rate-VO_2 regression equations and Frentsos and Baer estimated energy needs from dietary recommendations for endurance athletes.

The energy balance of female athletes in four sports (8 volleyball, 11 middle distance running, 7 ballet dancing, and 9 swimming) were studied by Hassapidou and Manstrantoni (2001) over two seasons. Athletes aged 18 – 26 years were compared to 10 control females aged 18 – 25 years. Long practice sessions for the non-competitive and competitive seasons were reported with volleyball players reporting the longest practice times: 2 – 4 hr/day for the non-competitive season and 1.5 – 3 hr/day (one to two training sessions) plus competition during the competitive season. Dietary records were kept for seven consecutive days by all subjects for one week of the non-competitive and one week of the competitive seasons. All foods and fluids were weighed on scales given to each athlete and later analyzed for kcal and nutrient content using the Microdiet computer program. During the same time periods, seven-day activity records were kept and used to calculate the EE by using the Compendium of Physical Activities (Ainsworth, Haskell, & Leon, 1993). The resting metabolic rate (RMR) was calculated using the equation of O. Owen, Kaule, and R. Owen (1986), and energy balance was calculated by subtracting the calculated EE from the reported EI. Hassapidou and Manstrantoni found that most athletes had a negative energy balance during both athletic seasons. During the non-competitive season, athletes' EI averaged 1816 ± 537 kcal vs. EE of 2311 ± 340 kcal; a 495 ± 439 kcal negative balance. For the competitive season, athletes' EI averaged 1868 ± 340 kcal vs. EE of 2338 ± 362; a 470 ± 521 kcal negative balance. No significant difference was reported for the EI of athletes vs. controls (e.g., athletes' training EI 1816 ± 537 kcal vs. controls' 1700 ± 493 kcal); however, EE was significantly higher for athletes vs. controls (e.g., athletes' EE during competition 2338 ± 363 kcal vs. controls' EE 1633 kcal). Limitations of this study included errors from assessing food intakes from self reported records that possibly contain some underreporting of foods as well as estimating EE from activity records and not from direct measurements. Hassapidou and Manstrantoni did note that athletes tended to lose weight and that athletes with the lowest energy intakes (< 1800 kcal) reported menstrual abnormalities.

Another study that examined energy balance was that of Trappe, Gastaldelli, Jozsi, Troup, and Wolfe (1997). They were interested in the total energy expenditure of female swimmers during high volume training lasting 5 – 6 hours per day. Subjects were five swimmers of the United States Swimming National Team. Subjects were observed for five days during training and assessed for body weight and composition on day 2 and 5 of the study. Average EI was estimated with Dietary records kept on day 3 and 4 and analyzed with the Food Processor software (ESHA Research, Salem, OR). Resting EE was directly measured on a non-training day by collection of expired air analyzed with a MGM Metabolic Monitor (Utah Medical). A noted difference between this study and those previously described (Kimber et al., 2002; Frentsos & Baer, 1997; Hassapidou &

Manstrantoni, 2001) was that Trappe et al. used a doubly labeled water (DLW) method to measure energy expenditure. The DLW method of assessing EE requires the consumption of a measured oral dose of water composed of a known amount of stable (non-radioactive) isotopes of both hydrogen (^{2}H) and oxygen (^{18}O). As explained by Ainslie et al. (2003), the technique is based on the assumption that as energy is expended, CO_2 and water are produced by the body. The CO_2 is lost through expiration; the water is lost in expiration, urine, sweat, and other evaporations. The ^{18}O is a component of both CO_2 and water, and it is lost from the body more quickly than the ^{2}H, which is a component of the body water but not part of the CO_2. The estimate of EE is made by determining the rate at which CO_2 is produced by analyzing the difference between the rate of loss of ^{18}O and ^{2}H. This DLW technique was used by Trappe et al. who collected baseline saliva samples from the swimmers on day 1 of their study after which athletes received measured doses of DLW. Initial saliva samples were compared to final samples taken on day 5 and used to estimate the total EE of activity. Results showed that athletes had a negative 43 ± 2% energy balance with total EE of 5593 ± 495 kcal/day on typical training days (swim, 17 ± 1.0 km/day). The authors stated that given that athletes maintained their body weight despite a large negative energy balance that underreporting of food intake and under consuming on record keeping days were probable contributors to the energy balance difference; however, they added that female swimmers may have found it hard to match the high energy requirement of their training and that weight loss would be hard to detect over such a short study period.

The DLW technique was also used by Edwards, Lindeman, Mikesky, and Stager (1993) to examine the energy balance of female endurance runners. Subjects were nine members of a university cross-country team who were observed over a seven day period where they averaged 6.5 ± 0.9 miles/day running and participated in two, 45 min resistance training sessions. One difference in the DLW technique of this study compared to Trappe et al. (1997) is that Edwards et al. measured EE with analysis of urine samples instead of saliva samples. Subjects completed a Food Attitude Scale and were trained by a registered dietitian to maintain food and activity records; follow-up training occurred on day 3 to ensure that the best possible records were kept. On day 7, all records were turned in and analyzed with the Nutritionist III software. A comparison of EI and EE resulted in a negative 32% energy balance: daily EE from DLW (2990 ± 415 kcal) was significantly greater ($p < 0.01$) than daily EI from food diaries (2037 ± 298 kcal). The authors also reported a negative correlation between EI vs. body weight ($r = -0.74$) as well as a negative correlation between body weight vs. food/attitude ($r = -0.78$) which meant that the heavier women self-reported lower EI and had lower body image scores than women with less weight. Edwards et al. reported similar results of a negative energy balance for female athletes as those previously reported (Kimber et al., 2002; Frentsos & Baer, 1997; Hassapidou & Manstrantoni, 2001; Trappe et al., 1997).

Characteristics of Volleyball Players

Research of the sport of volleyball has attempted to describe the physiological changes that happen during play. A study that addressed the energy demands and physiological requirements of competitive volleyball was that of Conlee, McGown, Fisher, Dalsky, and Robinson (1982). Subjects were six collegiate male volleyball athletes who were assessed for changes in blood glucose, lactic acid concentrations, and glycogen depletion of fast and slow twitch muscle fibers. Their average VO_{2max} was reported to be 56.4 ± 5.8 ml/kg/min, but the authors did not state how this was assessed. On the day of data collection, athletes played four 60 min matches with 60 min rest periods between each match and one final 90 min match at the end of the day. This experimental design was intended to simulate a day of tournament play. Blood samples were drawn before and after the first match and after the last match of the day and analyzed for glucose and lactic acid. Muscle biopsy samples were taken for the same time periods from the vastus lateralis and analyzed for glycogen concentration and for muscle typing (fast or slow twitch). Plasma glucose and blood lactic acid showed no effect ($p > .05$) after the first volleyball match, and these values did not change much throughout the entire day of play. Muscle glycogen did show a significant decrease of 22.8% ($p < .05$) after the first match and decreased a total of 40.0% over the whole day. Glycogen depletion was found in both slow and fast twitch muscle fibers, but after the first match, many more slow twitch fibers (> 20%) were depleted of glycogen than fast twitch fibers (~ 9%). Conlee et al. stated that the rest periods between matches accompanied by snacks eaten appeared to have been adequate to maintain glucose levels resulting in the sparing of muscle glycogen. They also believed that despite the many intense explosive movements of volleyball that the level of lactate (0.9 ± 0.1 mmol/l after the last match) may not have built up because there was enough time for it to be metabolized during the less intense periods. The authors found the volleyball athletes had

56.5 ± 4.2% fast twitch muscle fibers from vastus lateralis samples which they stated was similar to values of sprinters and jumpers who also perform comparable explosive activities.

The duration and intensity of exercise influence many metabolic processes and Künstlinger, Ludwig, and Stegemann (1987) examined the type of changes that occurred in hormone and electrolyte levels during volleyball matches. Subjects were eight female volleyball players (24.8 ± 2.3 years) from the German leagues who were studied during two regular matches lasting 92 and 85 min each. Each match consisted of five games with the observed team winning three out of five games. The long duration and the closeness of the final scores reflected a high physical and emotional stress for the athletes. Künstlinger et al. also evaluated the starting six players of the first male league for one match that they won in a 3:2 set. They measured metabolic parameters (lactate, glucose, and free fatty acids), electrolytes (Na^+, K^+, Mg^{2+}, and Ca^{2+}), and hormones (aldosterone, cortisol, and catecholamines) by analysis of venous and/or urinary samples. They reported similar results to those of Conlee et al. (1982) with low concentrations of lactate (2.54 ± 1.21 mmol/l) both during and after the matches. The authors believed that energy during the short exercise periods of rallies was supplied mostly by the breakdown of creatine phosphate and myoglobin stores with only small contributions from anaerobic glycolysis. The increase of 49.5 ± 26.4% in free fatty acids suggested to the authors that energy sources were restored aerobically during the rest periods by the oxidation of lipids. After volleyball play, serum concentrations increased for aldosterone (139.4 ± 55.3%) and cortisol (36%). The increased urinary excretion of adrenaline was similar to what had previously been reported for endurance sports; however, the urinary excretion of noradrenaline was comparable to values found during high intensity exercise. Conlee et al. suggested that the repeated change between short intense periods of exercise (9 s) followed by rest (12 s) may be a greater stimulus to the sympathoadrenal system than the changes between periods of intermediate and high intensity exercise typical of other interval sports such as basketball and tennis that have longer work-to-rest ratios. Künstlinger et al. concluded that volleyball play used both aerobic and anaerobic energy supplies and recommended that further studies be done to investigate the kinetics of changes in electrolytes and catecholamines during volleyball's many short intense play periods followed by rest periods.

Physical characteristics of volleyball players that might influence performance have been described by Lee, Etnyre, Poindexter, Sokol, and Toon (1989) who measured the flexibility properties of 24 men and 22 women from the United States National Olympic Festival Volleyball teams. The purpose of this study was to compare shoulder and hip flexibility to jumping performance to test the assumption that greater flexibility was related to better performance. Standing vertical jump (SVJ) and approach vertical jump (AVJ) were measured with a Vertec jump measuring device. Goniometer measures were made for range of motion (ROM) of transverse shoulder extension and hip flexion. Results showed a strong correlation between the SVJ and the AVJ for both men ($r = .84$, $p < .001$) and women ($r = .78$, $p < .001$). There was also a significant positive correlation between AVJ and hip ROM for the men ($r = .42$, $p < .03$). The women showed a significant negative correlation between SVJ and hip ROM ($r = -.54$, $p = .009$) and between AVJ and hip ROM ($r = -.47$, $p = .03$). No significant correlations were found between the shoulder ROM and either type of jumps. Lee et al. found opposite results with men and women. Greater hip flexibility was associated with greater AVJ in men, but women who had the greatest jump heights had the least hip flexibility. The authors stated that one possible explanation for opposite results could have been the anatomical differences in the hip joint between men and women and that increased hip flexibility may have been more beneficial for men. They also stated that women's flexibility was generally greater than that of men which agreed with the results found in this study (men: shoulder = 32.2°, hip = 87.3°; women; shoulder = 34.6°, hip = 96.1°). Further study was recommended to see how their results compared with other athletes in volleyball and other sports.

Volleyball game play is characterized by fast movements of running and jumping alternated with less intense movements in an unpredictable pattern. Laconi, Crisafulli, Sollai, Lai, and Concu (1998) were interested in quantifying the mechanical work efficiency of volleyball players as a possible method of evaluating their training efficiency. The index of mechanical work efficiency (μ') was defined as the extent to which metabolic energy was transformed into mechanical work output ($\mu' = W_{mec} / W_{oxy}$). The mechanical work output (W_{mec} = Joules/kg/min) was derived through video analysis software and was equal to the summation of the potential energy attributed to jumps, kinetic translational energy of the bust, and kinetic rotational energy of the trunk. The oxidative energy consumption (W_{oxy} = Joules/kg/min) was derived by VO_2 measured with a telemetry device (Cosmed K2) worn by the athletes during 15 min of volleyball game play. Subjects were 10 volleyball players (4 females and 6 males) who regularly trained 3-4 hour per day, 3 days/week, and played a competitive match once a week. Physiological measures were made for VO_2, pulmonary ventilation (V_E), and heart rate (HR) with the aid of the K2 portable telemetric system (Cosmed, Italy). After analysis of rest, attacking, and defense phases of movement, Lanconi et al. determined an index of mechanical work efficiency (μ') for each phase. Results showed that during the defense phase, the index of mechanical work efficiency was 2/3 of that during attack phase ($\mu' = 0.21 \pm 0.05$ vs. 0.57 ± 0.09). During attack phases, the mean value of $\mu' = 0.57 \pm 0.09$ was above the accepted maximal efficiency of contractile tissues ($\mu' = 0.25$), and the authors attributed this difference to the contribution of anaerobic energy during explosive movements of jumping and running. During defense, the $\mu' = 0.21 \pm 0.05$ was lower than 0.25, and this value along with a sustained elevation in both HR and V_E indicated to the authors that this time period was likely used for restoring anaerobic energy sources. They found during attack phases that VO_2 (ml/kg/min) and oxidative energy consumption (kcal/kg/min) were significantly greater ($p < .05$) than during defense (23.1 ± 3.3 vs. 18.9 ± 2.7 ml/kg/min and $0.12 \pm .02$ vs. 0.09 ± 0.01 kcal/kg/min, respectively). Although Lanconi et al. did not assess the total energy expenditure of volleyball play, their results for mechanical work efficiency during attack and defense phases indicated to them that anaerobic energy expended during attack phases was restored during defense and rest phases. These observations about the nature of energy sources and their restoration during volleyball play were in agreement with those stated by Conlee et al (1982) and Künstlinger et al. (1987).

Summary

Nutritional concerns have led many athletes to use supplements with the intention of maintaining health and improving performances (Froiland et al., 2004; Mullins et al., 2001; Kimber et al., 2002). Coaches have an important role in promoting healthy eating behaviors and adequate nutrition because of their close contact with athletes (Heffner et al., 2003; Hinton et al., 2004; Froiland et al., 2004). Analyses of nutritional status of NCAA Division 1 athletes, heptathletes and triathletes have revealed lower levels of CHO intakes than were thought to be adequate to support vigorous activities of athletes (Hinton et al., 2004; Mullins et al., 2001; Frentsos & Baer, 1997). The importance of adequate nutrients and kcal has been a common concern of research. When the energy balance of athletes from different sports (triathletes, volleyball, running, ballet, and swimming) has been studied, a common finding was that athletes tended to have significant negative energy balances (Kimber et al., 2002; Hassapidou & Manstrantoni, 2001; Trappe et al., 1997; Edwards et al., 1993).

Volleyball players have been studied for some of the physiological characteristics that may contribute to their overall performance. Muscle fiber type in the vastus lateralis has been found to be similar to that of sprinters and jumpers (Conlee et al., 1982). Performance differences due to flexibility have been found between male and female players (Lee et al., 1989). Studies of the metabolic changes of lactate, glucose levels, hormones, and mechanical work efficiency have all shared a common conclusion that volleyball is a physiologically taxing activity involving considerable activation of anaerobic metabolism. Short periods of high intensity activity requiring anaerobic energy are followed by short periods of less intense activity that most authors have speculated are used to restore these energy sources through oxidative means (Conlee et al., 1982; Künstlinger et al., 1987; Lanconi et al., 1998). The dietary intake assessed from weighed dietary records of volleyball players has been compared to the estimated EE from activity records in one study (Hassapidou & Manstrantoni, 2001), but no studies were found that determined energy balance through assessment of both EI from dietary diaries and EE from the combination of direct measurements during volleyball play and activity records. Past research points to the importance of adequate nutrition for performance and health, but further study is needed to directly assess the actual energy needs of volleyball athletes so that appropriate nutritional recommendations can be made.

Chapter 4. Methods

Subjects

Subjects for this study were 12 female volleyball team members playing for the University of Nebraska at Omaha (NCAA Division II). All subjects completed medical histories to ensure that they were healthy and free of any cardiovascular risks, musculoskeletal problems, diagnosed eating disorders, or substances banned by NCAA rules. Subjects were informed of the nature of the study and signed informed consents. This study was approved by the Institutional Review Board of the University of Nebraska Medical Center before initiation.

Experimental Design

This descriptive study of the bioenergetics of volleyball started with an instructional training session for subjects to explain the measurement and recording of all food and fluid intake necessary for the accuracy of a dietary diary and the recording of all physical activity for an activity log. Instructions were given by the primary investigator and under the guidance of a registered dietitian. The video *How to Keep a Food Diary* (National Health Video, Inc., 1994) was shown and food models and pictures were given to all subjects. Sample completed dietary logs were given to each subject to clarify the detail needed for proper analysis of dietary intake. The physical activity log was explained with each subject receiving a copy of the Compendium of Physical Activities (Ainsworth, 2002) that was used as a guide for recording appropriate descriptions of physical activities on log sheets. Subjects were instructed to record the physical activity from the Compendium that best described their activity for each 15 min period for 24 hours; from 12:00 am of one day until 12:00 am of the next day (Bouchard, Tremblay, Leblanc, Lortie, Savard, & Thériault, 1983). Recording 24 hour physical activity on logs has been found to estimate energy expenditure with less than 10% difference between the records and the criterion method of doubly labeled water (Conway, Seale, Jacobs, Irwin, & Ainsworth, 2002). Dietary diaries along with physical activity logs were recorded for three volleyball training days. The three day period for dietary records was chosen because it is a widely used method for estimating food intake of individuals when comparing group data and it helps to account for the day to day variations in daily intake (Burke, Cox, Cummings, & Desbrow, 2001). Subjects were asked to maintain their normal diets and training schedules throughout the study period. These records were reviewed with each subject after completion to clarify what was recorded and then used to calculate a mean value for energy intake and energy expenditure. Each athlete received a three ring binder containing written instructions for log keeping, picture samples of food serving sizes, the Compendium of Physical Activities, dietary diary log sheets, physical activity log sheets, and a mechanical pencil attached inside the cover.

During 12 separate team practice sessions over a three week period, one of the 12 subjects played volleyball while wearing the VO2000 portable metabolic device (see Figure 1 and Figure 2) for approximately 45 min. The VO2000 has a storage capacity of 180 data points; therefore, when data is recorded every 20 s, the analyzer unit is capable of storing data for 60 min. A 45 min data collection time was set to be within this limit. Heart rate was monitored with a HR monitor synchronized with the VO2000. Within two weeks before field data collection, each subject attended a preliminary testing session at the UNO Exercise Physiology Lab to record demographic information and to perform a familiarization exercise test while wearing the portable metabolic unit. This allowed subjects to experience exercise while wearing this apparatus. All team practice sessions were performed in the UNO Sapp Field House or the HPER building while under the direct supervision of the team coaches.

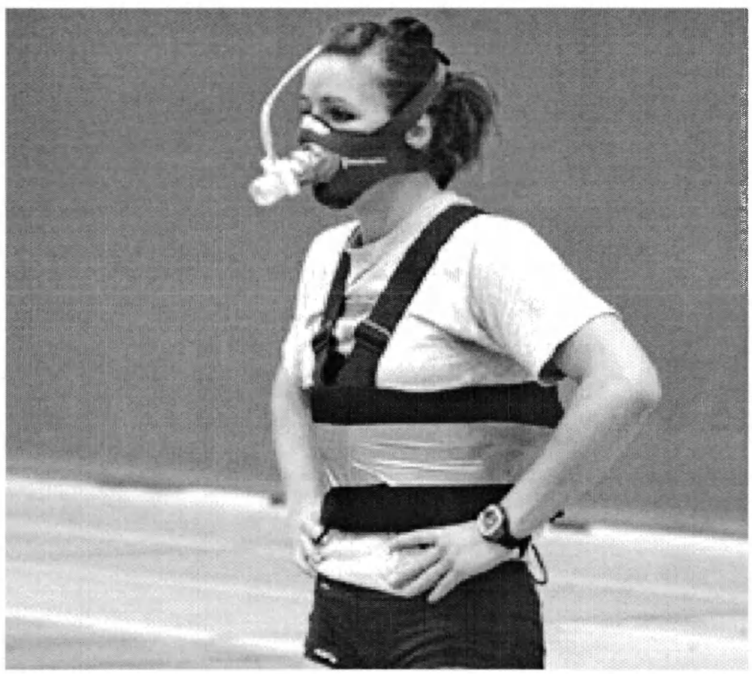

Figure 1. Athlete fitted with VO2000: face mask with pnuemotach, umbilical cord running overhead and connected to the main analyzer worn on the back, and battery pack mounted in harness on the chest and secured with neoprene belt and tape.

Figure 2. Side view of athlete showing fit of VO2000 analyzer module on the back and cushioned with thick sponge and secured with neoprene belt and tape.

Data Collection

Records for all athletes included descriptive data for age, height, weight, and percent body fat. Height and weight were measured with a medical rated scale (Detecto Medic; Detecto Scales, Inc., Brooklyn, NY). Body density was determined by skinfold assessment at three sites (right triceps, suprailiac, and thigh) with the use of the techniques and generalized equation for women developed by Jackson, Pollock, and Ward (1980). Harpenden skinfold calipers (Model 68875; Baty International, England) were used to measure the skinfold thickness at each site to obtain two scores within 1.0 mm of each other. The mean value of each site was summed and placed in the generalized equation for women. The Siri two-compartment equation was used to calculate the percent body fat from the body density calculation (Siri, 1956). The accuracy of the Jackson, Pollock, and Ward equation used with the Siri equation has been reported to be within ± 3.5% body fat value (Ross & Jackson, 1990).

Dietary intake was self-recorded throughout the day on log sheets distributed to each athlete for all food, fluids, and supplements consumed on three training days during the week surrounding their field testing date (see Appendix D). Standard home measures (e.g., inch, cup, fluid ounce, tablespoon, teaspoon, dry ounce, and pound) were used for serving size, volume, or weight of food and fluids. All physical activity was recorded for every 15 min period throughout the day on separate log sheets provided to each athlete for the 24 hour period (from 12:00 am of one day until 12:00 am of the next day) for the same three training days as the dietary diary record keeping (see Appendix E).

The VO2000 portable metabolic measurement device (Medical Graphics Corp., St. Paul, MN) was used to collect expired air for analysis and estimation of the kcal expenditure of approximately 45 min of team drills. Within two weeks before the field data collection, each subject participated in approximately 10 min of exercise consisting of running, jumping, and hitting a volleyball while wearing the VO2000 to allow the subject to experience what it felt like to exercise while wearing this apparatus. A Polar S610i HR monitor with a Polar T61 coded transmitter (Polar S610i Heart Rate Monitor; Polar Electro Oy, Kempele, Finland) was worn to record HR and this data was synchronized with the VO2000 data. On the field data collection date, the subject's body weight was recorded from the medical rated scale (Detecto Medic; Detecto Scales, Inc., Brooklyn, NY) followed by performance of a 5 to 10 min warm-up activity with the team under the direction of the coaches and then was fitted with the VO2000 and the Polar S610i which were worn for approximately 45 min of team practice.

The VO2000 metabolic measurement system is comprised of the VO2000 analyzer module with bumpers and harness clips, an external power supply (battery unit), control computer software, PreVent face mask, pnuemotach, umbilical cord connecting the pnuemotach to the analyzer module, two serial cables connecting the analyzer module to the battery unit and to the external computer (Gateway E-4200 Series; Gateway, Inc., Irvine, CA), and the control software (BreezeSuite 6.1B; Medgraphics Corp., St. Paul, MN). The O_2 analyzer was calibrated with an auto-calibration function a minimum of 30 min before testing. The analyzer module is capable of storing 180 consecutive data sets with a sampling frequency of 0.05 Hz. The analyzer was set to collect data every 20 s. After the athlete was fitted with the VO2000 unit, the main analyzer unit was disconnected from the computer for the approximate 45 min collection period. After the data collection period, the main analyzer unit was reconnected to the external computer and the stored data was downloaded. The validity of the VO2000 has been tested by Byard and Dengel (2002) by comparison to a MedGraphics CPX/D metabolic measurement system during multiple stage cycle ergometer exercise testing. Results confirmed the VO2000 produced comparable measures of VO_2 ($r^2 = 0.962$), VCO_2 ($r^2 = 0.968$, and V_E ($r^2 = 0.984$) all significant at $p < 0.0001$.

Data Analysis

Total EI in kcal was calculated using the Food Processor Nutrition Analysis and Fitness Software Version 7.5 (ESHA, 2000) from entries in the dietary diaries. With the exception of volleyball play, the Compendium of Physical Activities (Ainsworth, 2002) was used to estimate EE in kcal for all daily activities including sleeping, sitting, walking, exercise, etc. Total kcal used for EE during volleyball practice was calculated directly from data collected with the VO2000 metabolic unit.

Data collected with the VO2000 was studied before final computation of total EE for volleyball play. Outlying scores of VO_2 below 4 ml/kg/min and those above 70 ml/kg/min were not included in the final calculation of EE due to the low probability of the existence of these scores during this type of activity. Out of the approximately 1586 data points of VO_2 analyzed, only 34 scores lower than 4 ml/kg/min were eliminated and no scores above 70 ml/kg/min were found.

Minitab 14 statistical analysis software (Minitab, Inc., State College, PA) was used to calculate the mean, standard deviation ($M \pm SD$), and range for age, height, weight, % body fat, VO_2 during volleyball play, corresponding metabolic equivalent (MET) value of the VO_2, HR during on court VO2000 data collection, total min on the court during VO_2 data collection, kcal of energy expended on-court, kcal for daily EE, kcal for daily EI, and daily energy balance. The energy balance was calculated by subtraction of the mean EE from the mean EI. An independent t analysis was performed to test for a significant difference between the EE and the EI with a significance level set at $p = .05$. The effect size was calculated for results that demonstrated significance.

Chapter 5. Results

Demographic data for 11 subjects measured during preliminary testing in the UNO Exercise Physiology Lab is displayed in Table 1. Data from a twelfth subject was excluded from the final analysis due to illness during on-court data collection and the days of her recorded dietary diary and physical activity log. A study of the ranges of height, weight, and % body fat reveals the diversity of physical characteristics of these elite athletes. The minimum height was 163.8 cm with the maximum height of 186.7 cm; nearly a 23 cm difference. Weight ranged from 58.1 kg to 96.9 kg showing a 38.8 kg difference. The minimum % body fat was 14.9% and the maximum was 39.4%.

Table 1

Physical Characteristics of Subjects

Subject	Age (years)	Height (cm)	Weight (kg)	% Body Fat
1	20	172.1	68.3	29.5
2	19	172.1	87.4	39.4
3	20	177.2	69.1	19.1
4	22	183.5	96.9	36.9
5	22	168.9	58.1	16.5
6	21	184.2	72.7	26.8
7	20	174.6	62.4	15.2
8	19	184.4	69.1	28.1
9	22	179.7	73.1	26.9
10	19	186.7	72.6	23.9
11	21	163.8	61.5	14.9
M ($\pm SD$)	20.5 (1.2)	177.0 (7.0)	71.9 (10.8)	25.2 (7.9)
Min	19	163.8	58.1	14.9
Max	22	186.7	96.9	39.4

A summary of data collected for each athlete during volleyball team practice sessions is presented in Table 2. The mean VO_2 during team practice sessions was 25.03 ± 3.12 ml/kg/min which is equivalent to a 7.1 ± 0.9 MET. The mean length of time of VO2000 data collection and analyses was 47.1 ± 3.7 min. Heart rate data is for 10 of the 11 subjects due to a technical problem with the HR monitor during on-court data collection for one athlete. The mean HR was 153 ± 13 beats per min (bpm). Mean energy expended during on-court data collection was 419 ± 87 kcal which is equivalent to 8.9 kcal/min.

Table 2

Metabolic Measurements during Volleyball Team Practice Sessions

Subject	*M* VO_2 (ml/kg/min)	Equivalent MET (from *M* VO_2 values)	*M* HR (n=10, bpm)	Total Minutes (on-court data collection)	EE on-court (kcal)
1	24.85	7.1	153	46.33	397
2	31.30	8.9	172	44	607
3	25.25	7.2	151	45	403
4	25.22	7.2	136	40.33	493
5	23.38	6.7	136	45	307
6	24.32	6.9	153	52	460
7	27.09	7.7	137	52	441
8	21.51	6.1	155	47	349
9	20.57	5.9	167	53	350
10	29.55	8.4	170	46	481
11	22.24	6.4		47	322
M (± *SD*)	25.03 (3.12)	7.1 (0.9)	153 (13)	47.1 (3.7)	419 (87)
Min	20.57	5.9	136	40.33	307
Max	31.30	8.9	172	53	607

Note. EE = Energy Expenditure. EE is the actual total kcal for the time period of on-court data collection based on total VO_2 for each subject.

A visual representation of VO_2 for one subject during a team practice session is presented in Figure 3. This graph clearly demonstrates the higher VO_2 rates associated with active play times compared to lower levels of VO_2 during the short rest periods between drills. The mean VO_2 during the 44 min practice session in Figure 3 was 31.30 ml/kg/min with a peak VO_2 of 43.4 ml/kg/min.

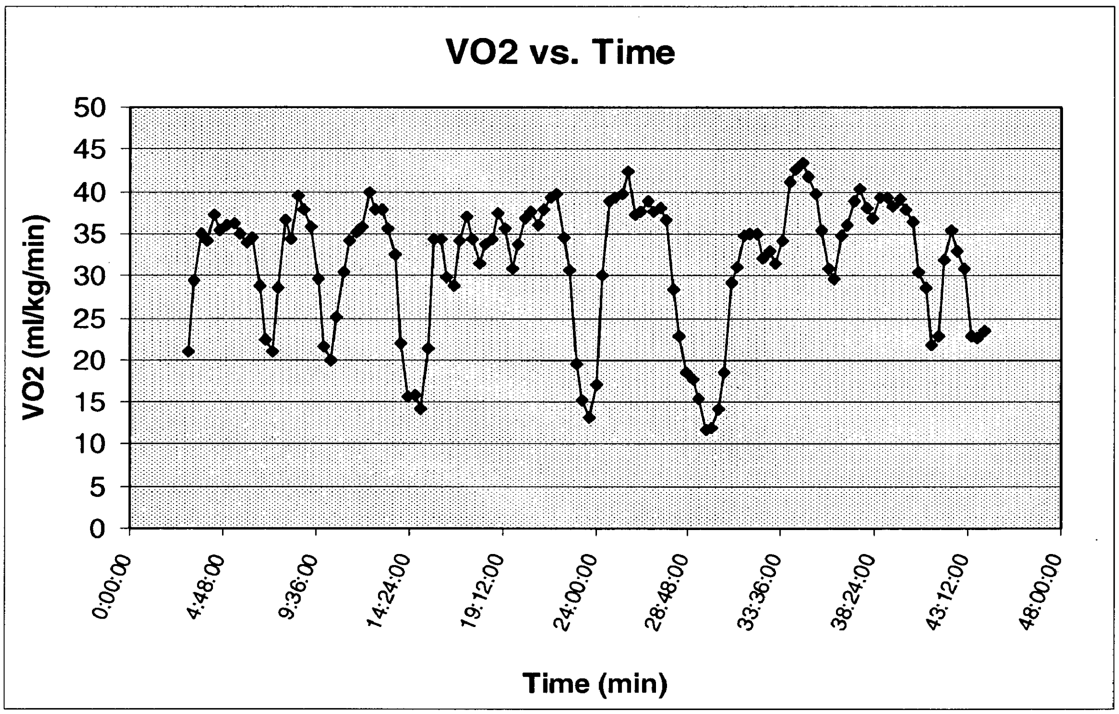

Figure 3. Representative VO_2 data collected with VO2000 analyzer for one subject. Data recorded every 20 s. *M* VO_2 = 31.30 ml/kg/min for this subject.

Figure 4 shows the recorded HR for the same athlete as that of Figure 3. Heart rate data is very similar in appearance to the VO_2 data showing the close relationship of these two variables. Peak HR in Figure 4 reached 189 bpm with a mean HR of 172 bpm for the 44 min of data collection.

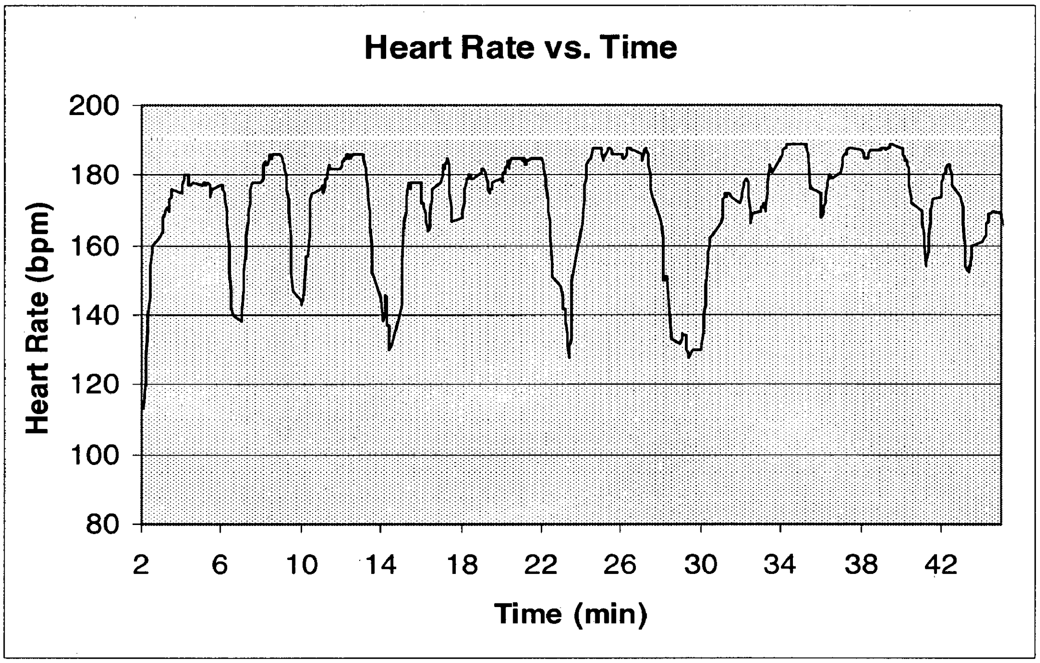

Figure 4. Representative heart rate data for one subject (same athlete as in Figure 3). Data recorded every 5 s. *M* heart rate = 172 bpm.

Nutritional analysis for EI in kcal from the 3-day dietary diaries and results calculated from the 3-day physical activities logs for EE are displayed in Table 3. Information is for 11 athletes due to the withdrawal of one subject because of illness. This table contains the energy balance for each subject as well as the mean energy balance of all subjects. The energy balance is defined as the difference between the calculated EI and EE. The mean daily kcal consumed in the form of food and fluids was 1861 ± 516 and the mean daily kcal expended for physical activity was 3630 ± 442. Results of an independent *t* test showed a significant negative energy balance of

1769 ± 507 kcal at the $p = .001$ level which represents a 48.7% negative energy balance. Individually, all subjects had negative energy balances ranging from -779 kcal to -2686 kcal. This indicated that all subjects used considerably more energy for physical activity than they consumed in the form of food and fluids during the 3-day diary analyses. The significant difference found between EI and EE had a large effect size of 4.0.

Table 3

Summary of Mean Daily Energy Intake, Energy Expenditure, and Energy Balance Analyses from Three Volleyball Training Days

Subject	*M* Daily Energy Intake (kcal)	*M* Daily Energy Expenditure (kcal)	Daily Energy Balance
1	1832	3640	-1808
2	2161	4341	-2180
3	2458	3559	-1102
4	2137	4269	-2132
5	1108	2774	-1666
6	1162	3848	-2686
7	1559	3262	-1703
8	2533	3312	-779
9	1529	3599	-2070
10	2569	3983	-1414
11	1422	3340	-1919
M (± *SD*)	1861 (516)	3630 (442)	-1769 (507)*
Min	1108	2774	-2686
Max	2569	4341	-779

* $p = 0.001$

Table 4 is an example of one day's dietary log for one subject. Three days of dietary logs from each subject were used to calculate the mean daily EI for each subject.

Table 4

Sample of One Day's Dietary Diary for One Subject with Corresponding Calculated Calorie Intake Values

Time of Day	Food	Quantity	Calories
8:00 am	Water	1 – 20 oz bottle	0
9:30 am	Pears, diced, canned	½ cup	62
9:30 am	Coffee (bold French roast)	6 cups	11
11:45 am	White bread	1 slice	90
	Turkey, 98% fat-free, pkg.	1 slice	30
	Gala apple, fresh	1 medium	80
	Orange, fresh	1 medium	64.4
	Pineapple, fresh, cut pieces	1 cup	75.95
	Semi-sweet milk chocolate chips	2 teaspoons	35.83
	Water	1 – 20 oz bottle	0
2:00 pm	Chocolate chip granola bar	1 each	77.14
3 – 5:30 pm	Gatorade	20 oz	150.56
8:00 pm	Cabbage, fresh, shredded	3 cups	66.75
	Baby carrots, organic	10 oz wt	107.73
	Pretzel sticks	1 oz. wt	111.38
	Picante sauce	2 tablespoons	10
	Lite vinegarette salad dressing	2 tablespoons	31.62
	Lite ranch dressing	½ teaspoon	9.17
	Jalapeno pepper,raw, chopped	1 each	10.8
	White fish, baked	4 oz	195.05
	Green beans, cooked	2 cups	75.6
	Onion, chopped, cooked	¼ cup	19.95
	Water	2 – 20 oz bottles	0
10:30 pm	Twizzlers cherry bites candy	40 pieces	208.2
	Additional water during day	3 – 20 oz bottles	0
		Total kcal	1523.13

Table 5 is a summary from the activity log for the same subject as in Table 4 and for the corresponding day as the record in Table 4. The total time spent at a particular MET level during this 24 hour period was combined for the purposes of this table. MET values were derived from *The Compendium of Physical Activities Tracking Guide*

(Ainsworth, 2002) except for the time spent at volleyball practice. The MET value for volleyball practice for each subject was derived from the direct on-court measurement of VO_2 made with the portable metabolic device. The subject in Table 5 had a 6.4 MET value from her on-court VO_2 measures. Examples of some MET values and their associated activities are the following: sleeping = 0.9 MET, sitting at home eating = 1.5 MET, driving a car or self care such as grooming = 2.0 MET, cleaning house vigorously = 3.0 MET, weight lifting = 6.0 MET. Three days of activity logs from each subject were used to calculate the mean daily EE for each subject.

Table 5

Activity Log Summary of Energy Expended (kcal) during one 24 Hour Period for One Subject

Met Value of Activity	Min Spent at MET	Body Mass (kg)	Kcal Expended
0.9	450	61.5	435.88
1.5	15	61.5	24.22
1.8	300	61.5	581.18
2.0	345	61.5	742.61
2.3	30	61.5	74.26
2.5	30	61.5	80.72
3.0	15	61.5	48.43
3.3	75	61.5	266.37
6.0	60	61.5	387.45
6.4	120	61.5	826.56
Totals	1440		3467.68

Note. Activity summary is for same subject and same 24 hour period as in Table 4. Calculation of kcal expended assumed the value of one MET equal to 3.5 ml/kg/min of VO_2 and one liter of VO_2 = 5 kcal.

Chapter 6. Discussion

Volleyball studies have considered a number of the different characteristics of volleyball such as biomechanical aspects of play while measuring VO_2 (Lanconi et al., 1998), metabolic changes in hormones during play (Künstlinger et al., 1987), and changes in lipid metabolism (Bonetti et al., 1988). The energy requirement of volleyball athletes has only been addressed in a limited number of studies; one assessed stored energy through muscle biopsy samples in male volleyball athletes (Conlee et al., 1982), and another reported the energy balance of four sports including volleyball with negative energy balance recorded for volleyball athletes (Hassapidou & Manstrantoni, 2001). Current literature did not reveal any studies that measured the energy balance of female volleyball athletes on training days with the use of actual on-court measures of EE followed by a comparison to written records of mean EI during the same time period. The purpose of the present novel study was to derive the energy balance of female collegiate volleyball athletes on training days. This was accomplished by using indirect calorimetry with the aid of a portable metabolic measurement device for on-court analysis of EE in addition to detailed physical activity records used to calculate EE for all other daily activities and comparing daily EE to daily EI calculated from dietary diaries recorded for the same time period.

The hypothesis stated that a significant negative energy balance would be found, and results did confirm this hypothesis. A 48.7% negative energy balance of 1769 (± 507) kcal ($p = .001$) existed with all subjects individually having negative energy balances ranging from -779 kcal to -2686 kcal. The results demonstrated a large effect size of 4.0.

Although a negative balance was predicted, the size of the negative balance was larger than expected but similar to what others have found: 43% negative balance in female swimmers (Trappe et al., 1997) and 42% negative balance in triathletes (Frentsos & Baer, 1997). Alternatively, the resulting 48.7% negative balance was larger than the 32% negative balance of female endurance runners (Edwards et al., 1993) and the 21% negative balance of four female sports including volleyball (Hassapidou & Manstrantoni, 2001). A common concern of many researchers has been the limitations associated with the estimation of both EE and EI.

Previous studies noted underreporting food servings or undereating equaling about 20% - 29% during record keeping for estimating EI (Trappe et al., 1997; Burke et al., 2001; Hassapidou & Manstrantoni, 2001; Hinton et al., 2004; Rennie, Siervo, & Jebb, 2006), and a similar limitation equaling about 1.2% - 37% for the overestimation or underestimation of the time spent in activity in self-reported daily activity logs used in estimating EE (Ainslie et al., 2003). Some of the error involved with self-reported data may arise due to the instrument used such as dietary recalls or physical activity inventories which require the subject to rely on memory of things that have occurred in the past. Earlier investigators had concluded that to achieve optimal validity of physical activity records that it was necessary to have subjects willing to comply with the requirements of the study and to provide careful instructions to the subjects (Conway et al., 2002). A possible major limitation of the present study included the error connected with self-reported food diaries and activity logs. After a close examination of previous research for techniques that would bring the most accurate results as well as being reasonably achievable by subjects of the current study, multiple steps were developed in an attempt to minimize the inherent errors surrounding self-reported data.

To minimize error associated with self-reported food and physical activity logs, the subjects attended an instructional meeting where they were shown a video about record keeping and given verbal instructions about how to measure and accurately record food servings. Models of food sizes and measuring equipment were demonstrated during this meeting, and each subject was given a three-ring binder for record-keeping. Each binder had written instructions for dietary diaries and physical activity logs, diagrams of food sizes to be used for estimating serving sizes, samples of completed dietary diaries and physical activity logs, a complete *Compendium of Physical Activities Tracking Guide*, adequate copies of dietary diary and physical activity log sheets for three-day recording, and an attached mechanical pencil. The complete *Compendium of Physical Activities Tracking Guide* was given to all subjects to help them describe their physical activity with adequate detail so that the best possible estimation of EE for physical activity could be made. The subjects were also instructed to keep their binder with them throughout each day of record keeping so they could record both food intake and physical activity as they occurred. After the completed dietary and physical activity records were turned into the investigator, the records were reviewed and a follow-up individual interview was conducted to clarify any questions that came up during the review.

The volleyball athletes in this research had a mean EE of 419 (± 87) kcal during approximately 47 min of on-court data collection. When this value is extrapolated forward for the average daily practice session of two hours, it equals about 1070 kcal expended during a typical practice session. NCAA rules limit the number of hours that a team can hold a required practice during spring off-season training to a maximum of 20 hours per week. The subjects of this study were participating in four practice sessions per week each lasting two hours, and the athletes were also doing four hours of weight lifting per week. All of this activity adds up to a considerable amount of expended kcal. For the subjects of this study, the responsibility for all meal preparation and choice of foods was entirely up to each person. The athletes did not eat at a training table or have meals paid for by the university. If athletes do not attain adequate nutrition, they may not be able to achieve their full potential for performance; obtain enough energy and nutrients to support their needs for training, competition, and recovery; or acquire the essential fats and micronutrients needed for the immune system and antioxidant protection (Clark, 1999; Pipe, 2001; Venkatraman & Pendergast, 2002; Hinton et al., 2004). It is suspected that some of the negative 48.7% energy balance can be accounted for by errors involved in self-report. This includes the possibility that some subjects experienced the Hawthorne effect whereby they knowingly or unknowingly altered their behavior because they knew that their records would be analyzed. Nevertheless, it is likely that a number of these athletes may fall into a category of those not attaining adequate energy intakes.

A better understanding of the relatively high energy requirement of volleyball can be obtained by analysis of the VO_2 and HR data in Figures 3 and 4. These figures clearly demonstrate the nature of volleyball play with many high-intensity bouts of activity including jumping, spiking, blocking, diving, and running followed by short rest periods. Even though athletes appear to be standing and not exercising at times, it is obvious that they expend a large amount of energy over the course of their training sessions. The mean VO_2 of 25.03 (± 3.12) ml/kg/min includes many periods of high-energy explosive moves and attack phases followed by periods of relative rest (during less intense exercise) and total rest (during coaching sessions). This VO_2 value is greater than but similar to what had been previously reported by Lanconi et al. (1998) when they measured VO_2 during 15 min of volleyball play (23.1 ± 3.3 ml/kg/min during attack phases and 18.9 ± 2.7 ml/kg/min during defense phases). The equivalent MET value for aVO_2 of 25.03 (± 3.12) ml/kg/min is 7.1 which compares to activities such as competitive badminton, climbing hills, racquetball, soccer, and tennis (Ainsworth, 2002).

The sport of volleyball is often described as an anaerobic sport because of the power moves used during play: jumping, dashing, spiking, running, and diving. The relatively high mean VO_2 found over the course of on-court analysis demonstrates that a considerable amount of aerobic metabolism took place. Energy for the quick power moves lasting 10 – 20 s is mainly supplied by stored energy in the muscle in the form of phosphagens with some contribution from anaerobic glycolysis (Künstlinger et al., 1987). During the rest periods between plays, the aerobic system is constantly in the process of restoring phosphagens and shuttling lactate produced during anaerobic glycolysis (Margaria, Oliva, Di Prampero, & Cerretelli, 1969). Because high intensity activity is repeated many times during training sessions and rest periods are short, aerobic metabolism remains elevated throughout the extended training period. This elevated VO_2 reflects the results presented here with a substantial amount of energy (1070 kcal/ 2 hr training session) required to sustain the athlete during training.

Chapter 7. Summary and Conclusions

The purpose of this study was to examine the bioenergetics of female collegiate volleyball players during training and to establish the energy balance of training days. One of the goals of this research was to take direct measures of EE for an extended period of time during team practice sessions with the use of indirect calorimetry. This allowed for a better estimation of the energy cost of volleyball practice sessions than had previously been done.

In conclusion, it was found that female collegiate volleyball athletes expended considerable energy during practice sessions: approximately 1070 kcal per two hour training session. The athletes demonstrated a significant negative balance of 1769 (± 507) kcal at the $p = .001$ level which represented a negative 48.7% balance. Some portion of the difference found in the energy balance may be attributed to errors associated with self-report from dietary and physical activity records. These results indicate a need to look closer at possible intervention techniques to improve the athletes' ability to achieve adequate energy intake. Nutrition provides the fuel for energy production, optimal immune system function, and sports performance. It is possible that some nutrition education early in the training season may prove beneficial for athletes.

Information recorded during this research using indirect calorimetry will add to the body of knowledge about EE involved in collegiate level volleyball. This may be useful for both athletes and coaches when they are planning strategies to reach high levels of health and performance on and off the volleyball court. Further research is needed to investigate if interventions of nutritional supplementation or education might help female collegiate volleyball athletes achieve a more beneficial energy balance.

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Appendix A

THE ADULT CONSENT FORM

BIOENERGETICS ANALYSIS OF FEMALE VOLLEYBALL

INVITATION

You are invited to take part in this research study. The information in this form is meant to help you decide whether or not to take part. If you have any questions, please ask.

WHY ARE YOU BEING ASKED TO BE IN THIS RESEARCH STUDY?

You are being asked to be in this study because you play volleyball on the University of Nebraska at Omaha (UNO) women's volleyball team and are between the ages of 19 and 35 years. You may participate if you are free from any major cardiovascular risks, musculoskeletal problems, and diagnosed eating disorders. If you are pregnant, nursing an infant, or plan to become pregnant during this study, you may not be in this study.

WHAT IS THE REASON FOR DOING THIS RESEARCH STUDY?

The purpose of this study is to determine the calories used during practice sessions of volleyball, the calories used in other activities during a 24 hour period on a volleyball team training day, and the calories consumed in food and fluids during a 24 hour period on a volleyball team training day. These values will be compared to determine the energy balance of a typical volleyball team training day.

WHAT WILL BE DONE DURING THIS RESEARCH STUDY?

You will be asked to play volleyball up to 12 times over about a five week period with other members from your team for 45 minutes during regularly scheduled team practices. Practice sessions will be supervised by the team coaches and held in the UNO Sapp Field House or the Health, Physical Education, and Recreation Building.

You will play as a subject of data collection in any one of the up to 12 team practice sessions and will be asked to wear a device that monitors how much oxygen and energy you expend during the activity. While wearing the portable measuring device you will be prohibited from diving and/or rolling on the floor in order to protect you from injury and to protect the equipment from damage. In addition, you will be asked to maintain a dietary diary and activity log for three regular volleyball team training days_while maintaining your customary eating and activity practices.

As a subject in this research study, you will also be asked to participate in a preliminary testing at the UNO Exercise Physiology Laboratory. After measuring your height and weight with a medical grade scale, skinfold thickness will be measured at three sites of your body to estimate your body fatness. You will then be asked to walk/run on a treadmill for 10 minutes at a self-selected pace while wearing a breathing mask and portable monitoring device strapped to your trunk that measures how much oxygen your body uses each minute. Your heart rate will be measured by an electronic wristwatch from an electrode belt attached to your chest. After the treadmill test, you will be given detailed instructions on how to maintain a three day dietary diary and activity log along with log sheets for recording information.

You will be asked to avoid having high intensity and/or volume of physical activities within 24 hours before each session. Also, you will be asked to avoid eating for several hours before each session. Additionally, you will be asked to stay well hydrated the day before and the day of each session.

WHAT ARE THE POSSIBLE RISKS OF BEING IN THIS RESEARCH STUDY?

The potential risks associated with performing a treadmill test as well as playing volleyball during team practice sessions include injuries to the muscles, ligaments, tendons and joints, fainting, dizziness, disorders of the heart rhythm, and very rare instances of heart attack, stroke, or even death.

Potential discomfort associated with playing volleyball during team practices with the portable monitoring device includes perception of breathing difficulty.

WHAT ARE THE POSSIBLE BENEFITS TO YOU?

The potential benefits to you include knowledge of the results of the study. Also you will receive knowledge of your results and an estimate of the calories that you consume in the form of food and fluids and the calories that you use to support your activity throughout the day on a typical team training day. This information may be useful in terms of improving/maintaining your nutritional preparation for volleyball training.

You may not get any benefit from being in this research study.

WHAT ARE THE POSSIBLE BENEFITS TO OTHER PEOPLE?

The potential benefit to other people in society includes knowledge of the energy cost of playing volleyball. By applying these findings, volleyball coaches and related field professionals as well as competitive and recreational volleyball players may be able to make decisions as to whether or not changes need to be made to improve their nutritional preparation in order to enhance volleyball performance.

WHAT ARE THE ALTERNATIVES TO BEING IN THIS RESEARCH STUDY?

Instead of being in this research study, you can choose not to participate.

WHAT WILL BEING IN THIS RESEARCH STUDY COST YOU?

There is no cost to you to be in this research study.

WILL YOU BE PAID FOR BEING IN THIS RESEARCH STUDY?

You will not be paid to be in this research study.

WHAT SHOULD YOU DO IF YOU ARE INJURED DURING THIS RESEARCH STUDY?

If you are injured as a direct result of being in this study, you should immediately contact one of the people listed at the end of this consent form. Immediate emergency medical treatment for this injury will be available at The Nebraska Medical Center. However, it is the policy of UNO, UNMC, UNMC Physicians, and The Nebraska Medical Center not to pay for any required treatment. Agreeing to this does not mean you have given up any of your legal rights.

HOW WILL INFORMATION ABOUT YOU BE PROTECTED?

You have rights regarding the privacy of your medical information collected before and during this research. This medical information, called "protected health information" (PHI), includes demographic information (like your address and birth date), the results of physical exams, blood tests, x-rays and other diagnostic and medical procedures, as well as your medical history. You have the right to limit the use and sharing of your PHI, and you have the right to see your medical records and know who else is seeing them.

By signing this consent form, you are allowing the research team to have access to your PHI. The research team includes the investigators listed on this consent form.

Your PHI will be used only for the purpose(s) described in the section "What is the reason for doing this research study?"

Your PHI will be shared, as necessary, with the Institutional Review Board (IRB) and with any person or agency required by law. All of these persons or groups listed are obligated to protect your PHI.

You are authorizing us to use and disclose your PHI for as long as the research study is being conducted.

You may cancel this authorization to use and share your PHI at any time by contacting the principal investigator in writing. If you cancel this authorization, you may no longer participate in this research. If you cancel this authorization, use or sharing of future PHI will be stopped. The PHI which has already been collected may still be used.

The results of clinical tests and therapy performed as part of this research may be included in your medical record. The information from this study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential.

WHAT ARE YOUR RIGHTS AS A RESEARCH SUBJECTS?

You have rights as a research subject. These rights have been explained in this consent form and in The Rights of Research Subjects that you have been given. If you have any questions concerning your rights, talk to the investigator or call the Institutional Review Board (IRB), telephone (402) 559-6463.

WHAT WILL HAPPEN IF YOU DECIDE NOT TO BE IN THIS RESEARCH STUDY?

You can decide not to be in this research study. Deciding not to be in this research study will not affect your relationship with the investigator or UNO. You will not lose any benefits to which you are entitled.

WHAT WILL HAPPEN IF YOU DECIDE TO STOP PARTICIPATING ONCE YOU START?

You can stop being in this research study ("withdraw") at any time before, during, or after you begin participation. Deciding to withdraw will not affect your relationship with the investigator or UNO. You will not lose any benefits to which you are entitled. You may be taken off the study if you don't follow instructions of the investigator or the research team.

DOCUMENTATION OF INFORMED CONSENT

You are freely making a decision whether to be in this research study. Signing this form means that (1) you have read and understood this consent form, (2) you have had the consent form explained to you, (3) you have had your questions answered and (4) you have decided to be in the research study.

If you have any questions during the study, you should talk to one of the investigators listed below. You will be given a copy of this consent form to keep.

____________________	____________	____________
Signature of Subject:	Date:	Time:

My signature certifies that all the elements of informed consent described on this consent form have been explained fully to the subject. In my judgment, the participant possesses the legal capacity to give informed consent to participate in this research and is voluntarily and knowingly giving informed consent to participate.

____________________	____________
Signature of Investigator:	Date:

My signature certifies that I have authorized the investigator signing above to document the obtainment of informed consent, and he/she has the necessary clinical expertise and sufficient knowledge about the protocol and IRB consent requirements to document obtainment of consent. In my judgment, valid informed consent has been obtained from the subject.

____________________	____________
Signature of PI:	Date:

AUTHORIZED STUDY PERSONNEL

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Appendix B

Medical History Form

Date: ____________________ Age: ____________________

Name: ____________________ Sex: ____________________

Address: ____________________ Weight (lbs.): ____________________

Employment: ____________________ Height (inch):

____

Address: ____________________

Phone: ____________________ (home)

Phone: ____________________ (work)

Name of Personal Physician: ____________________

Address: ____________________

Have you been hospitalized within the last two years? ____________________

If yes, please explain:

____

Check the following which have occurred in your past medical history:

Heart Attack __________

High Blood Pressure __________

Chest Discomfort __________

ECG Abnormality __________

Stroke __________

Obesity __________

Unexplained Weight Gain or Loss __________

Diabetes __________

High Blood Pressure __________

Arthritis, Bursitis, Gout or Joint Inflammation __________

Epilepsy __________

Asthma __________

Emphysema __________

Bronchitis __________

Shortness of Breath __________

Lightheadedness or Fainting __________

Heat Illness __________

Allergy __________

Asthma __________

Eating Disorder __________

Other (explain)

____

List any medication(s) you are presently taking and condition(s) being treated.

____

____

List and describe any condition you have which may affect your ability to participate in strenuous physical activity.

____

____

Any family history of: (check if yes and indicate age of occurrence)

	Age of Occurrence	Who (mother, father, sibling aunt, uncle, grandparents)
Death before age 60	________	________________
Heart disease	________	________________
High blood pressure	________	________________
Diabetes	________	________________
Stroke	________	________________
Obesity	________	________________
Asthma	________	________________
Emphysema	________	________________

Weight History (lbs.)

High-school graduation	________
One year ago	________
Now	________
Maximum ever	________
When?	________

Smoking History

Ever? __________

Now? __________

What? __________

How often? __________

How much? __________

Attempted to stop? __________

Physical Activity History

Describe any physical activities that you have participated in during the last 12 months.

Activity	# of days per week	# of minutes per session	# of weeks or months of consistent involvement

Describe any physical activities that you have participated in during the last 6 weeks.

Pregnancy and/or breast feeding (<u>only females</u>)

Are you currently a pregnant or breast feeding woman? __________

Do you currently have child-bearing potential? __________

Appendix C

Data Collection Form

Name:					**Date:**		
Age:		**Consent Form signed:**					
DOB:		**Medical History form:**					
		Record Keeping Training:					
		Log Book issued:					
Preliminary Testing:					**Date:**		
		Height:					
		Weight:					
		Skinfolds	**Triceps**	**Suprailiac**	**Thigh**		
		1					
		2					
		3					
		Average =					
				Sum of SF:			
				% Body Fat:			
				VO2000 test run: (time, mph)			
Field Testing:					**Date:**		
		Weight:					
		HR Monitor:					
		VO2000:					
			Start Time:				
			End Time:				
			Total Time:				
	Notes:						
	Training Activity Description:						

Appendix D

Dietary Diary

Time of Day	Food (Give name of food or fluid; name brand if it you know it; how food was packaged: frozen, fresh, or canned; how prepared: raw, baked, fried, or steamed)	Quantity (teaspoons, tablespoons, cups, ounces, pounds, inches, or pieces)

Appendix E

Time of Day	Activity Refer to the Compendium: write category & specific activity
12:00 am – 12:15 am	
12:15 am – 12:30 am	
12:30 am – 12:45 am	
12:45 am – 1:00 am	
1:00 am – 1:15 am	
1:15 am – 1:30 am	
1:30 am – 1:45 am	
1:45 am – 2:00 am	
2:00 am – 2:15 am	
2:15 am – 2:30 am	
2:30 am – 2:45 am	
2:45 am – 3:00 am	
3:00 am – 3:15 am	
3:15 am – 3:30 am	
3:30 am – 3:45 am	
3:45 am – 4:00 am	
4:00 am – 4:15 am	
4:15 am – 4:30 am	
4 30 am – 4:45 am	
4:45 am – 5:00 am	
5:00 am – 5:15 am	
5:15 am – 5:30 am	
5:30 am – 5:45 am	
5:45 am – 6:00 am	
6:00 am – 6:15 am	
6:15 am – 6:30 am	
6:30 am – 6:45 am	
6:45 am – 7:00 am	
7:00 am – 7:15 am	
7:15 am – 7:30 am	
7 30 am – 7:45 am	
7:45 am – 8:00 am	
8:00 am – 8:15 am	
8:15 am – 8:30 am	
8:30 am – 8:45 am	
8:45 am – 9:00 am	
9:00 am – 9:15 am	
9:15 am – 9:30 am	

Time of Day	**Activity** Refer to the Compendium: write category & specific activity
9:30 am – 9:45 am	
9:45 am – 10:00 am	
10:00 am – 10:15 am	
10:15 am – 10:30 am	
10:30 am – 10:45 am	
10:45 am – 11:00 am	
11:00 am – 11:15 am	
11:15 am – 11:30 am	
11:30 am – 11:45 am	
11:45 am – 12:00 pm	
12:00 pm – 12:15 pm	
12:15 pm – 12:30 pm	
12:30 pm – 12:45 pm	
12:45 pm – 1:00 pm	
1:00 pm – 1:15 pm	
1:15 pm – 1:30 pm	
1:30 pm – 1:45 pm	
1:45 pm – 2:00 pm	
2:00 pm – 2:15 pm	
2:15 pm – 2:30 pm	
2:30 pm – 2:45 pm	
2:45 pm – 3:00 pm	
3:00 pm – 3:15 pm	
3:15 pm – 3:30 pm	
3:30 pm – 3:45 pm	
3:45 pm – 4:00 pm	
4:00 pm – 4:15 pm	
4:15 pm – 4:30 pm	
4 30 pm – 4:45 pm	
4:45 pm – 5:00 pm	
5:00 pm – 5:15 pm	
5:15 pm – 5:30 pm	
5:30 pm – 5:45 pm	
5:45 pm – 6:00 pm	
6:00 pm – 6:15 pm	
6:15 pm – 6:30 pm	
6:30 pm – 6:45 pm	
6:45 pm – 7:00 pm	
7:00 pm – 7:15 pm	

Time of Day	**Activity** Refer to the Compendium: write category & specific activity
7:15 pm – 7:30 pm	
7 30 pm – 7:45 pm	
7:45 pm – 8:00 pm	
8:00 pm – 8:15 pm	
8:15 pm – 8:30 pm	
8:30 pm – 8:45 pm	
8:45 pm – 9:00 pm	
9:00 pm – 9:15 pm	
9:15 pm – 9:30 pm	
9:30 pm – 9:45 pm	
9:45 pm – 10:00 pm	
10:00 pm – 10:15 pm	
10:15 pm – 10:30 pm	
10:30 pm – 10:45 pm	
10:45 pm – 11:00 pm	
11:00 pm – 11:15 pm	
11:15 pm – 11:30 pm	
11:30 pm – 11:45 pm	
11:45 pm – 12:00 am	